NASA/GSFC
Wallops Flight Facility

Flight Modem

SSC Maxus Test Flight

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1 Purpose

1.1 This document explains the Flight Modem and the data it collected while flying onboard a Swedish Space Corporation (SSC) Maxus Test sounding rocket launched February 19, 2001 from Esrange, Sweden. This is the first example of using commercially available components combined to operate as a LEO communications system and used the Globalstar satellite communications network as a means to transmit telemetry between a spacecraft and the ground. Analysis of data collected during this flight and explanations are included.

1.2 Scope

Presentation of the Flight Modem data gathered during the MAXUS TEST sounding rocket flight 19 February 2001.

1.3 Structure

This RCP consists of 5 sections and an appendix:

- Section 1 introduces the document and describes its scope
- Section 2 contains reference document information
- Section 3 describes Flight Modem systems
- Section 4 describes the Flight Modem Data
- Section 5 Data Analysis
- Section 6 Conclusion

2 DOCUMENTS

2.1 Applicable Documents

Applicable documents take precedence over the information in this document.

None.

2.2 Reference Documents

Reference documents that contain relevant information concerning this document are:

1. SSC/WFF Interface Control Document (ICD) for GPS Flight Modem Experiments on SCC Sounding Rocket (Launch from Kiruna, Sweden) Revised 01/05/01
2. SSC/WFF (MAXUS4) Instrumentation Block Diagram Revised 12/20/00
3. Flight Modem Sounding Rocket and Balloon Data Flow Diagram, 10/30/00
4. GSP-1620 Reference Manual Rev. B, 10/30/00
5. (ADD RLC DOCUMENTS HERE)

3.0 Flight Modem Systems

3.1 Flight Modem Flight Computer

The Flight Modem flight computer is a RLC Enterprises, Inc.(http://www.RLC.com) CE Minus/CE Plus embedded computer system running Windows CE 3.0 operating system. The computer system connects via RS-422 and RS-232 interfaces to other parts of the Flight Modem system. The Windows CE 3.0 operating system resides in ROM programmed by RLC and an 8Mbyte solid state hard drive holds application specific software, Flight Modem software and data logs generated by the flight computer. The flight computer is responsible for system status reporting and recording, GSP-1620 packet data modem control, and recording of Ashtech G12 GPS data.

The flight computer received GPS data on its RS-422 interface and stored it to disk at a rate of two samples per second. Due to difficulties programming the flight computer, sampling varied during the flight from twice per second to once per several seconds. This programming issue did not affect the quality of GPS data stored during the sampling error period, only the number of samples recorded. The programming difficulty was to due to flushing data from an internal buffer during a flight in the event that ?a computer reset or flight computer operating anomaly occurs. Due to time constraints, this sampling error was not corrected prior to flight.

The GPS data recovered from the Flight Modem is comparable to the GPS data received in the telemetry downlink during the flight and extends well past the end of the flight. GPS data received on the ground in the telemetry stream stopped when the rocket went out of view of the receiving ground based antenna. It is worth mentioning that the Flight Modem continued to operate and log GPS data as well as making calls to Globalstar after touchdown of the payload proving another concept of this system as a ground recovery tool.

The flight computer simultaneously recorded GPS data and controlled the GSP-1620 packet modem as described in section 3.2. The flight computer instructs the GSP-1620 modem to make a Markov call to the Globalstar system then poll and record to disk the GSP-1620 modem Markov call status. Polling of GSP-1620 status was at a rate of 1 sample per 6 seconds and was comprised of call status and Markov status. The flight software was written to determine whether Globalstar service as available, and the modem had registered itself in the Globalstar gateway. Once these conditions were met, the flight computer then initiated a Markov call to the gateway. In the event of call termination, the flight computer automatically reset the modem, then waited until service was available again and registration had taken place before reestablishing the Markov call.

Due to unavailability of a packet enabled gateway in Europe, Markov calls were placed between the Flight Modem and Globalstar instead of packet data calls. Markov calls are loop back calls between the user and Globalstar, which simulate data flow and provide signal quality information. (I would move this explanation of what a Markov call is and why we use it to somewhere above the section discussing Markov calls. You may want to combine this with the last paragraph in 3.2.

3.2 Qualcomm Model GSP-1620 Packet Data Modem

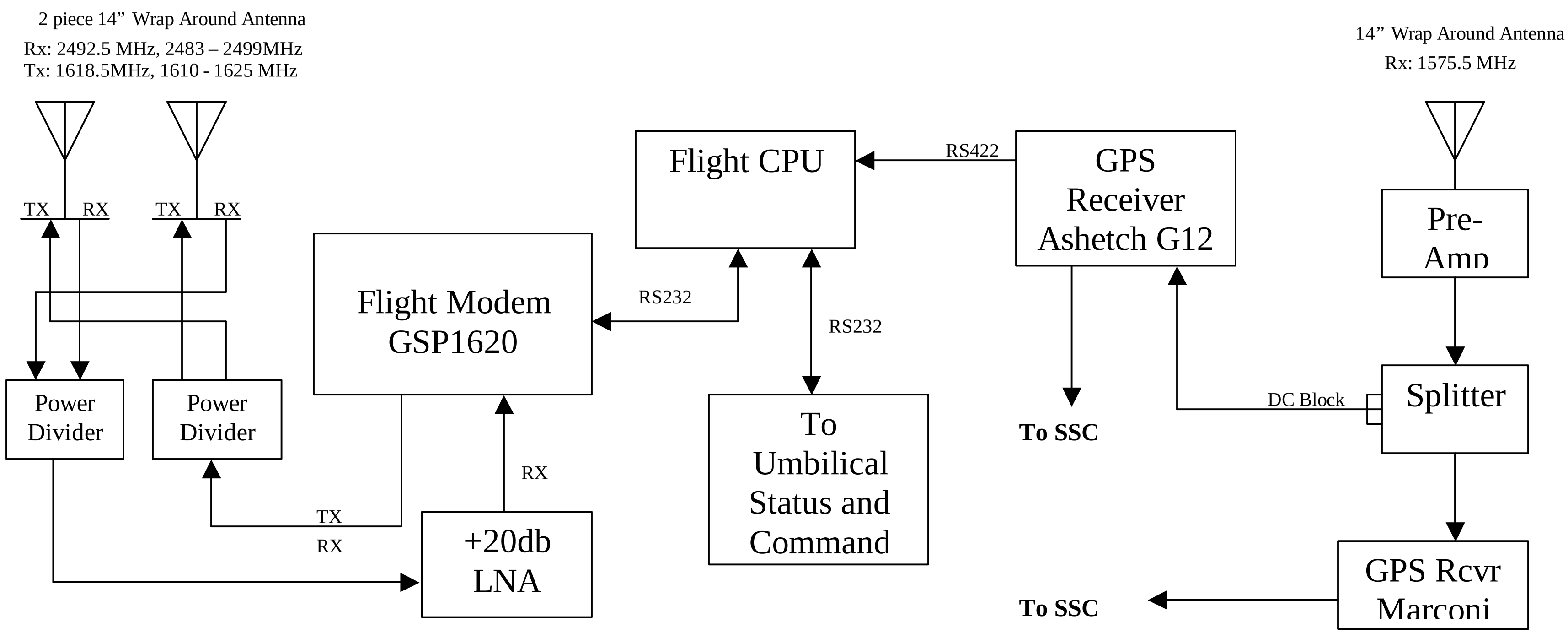
The Qualcomm Model GSP-1620 Packet Data Modem is a COTS available product allowing IP communications between users and the Internet over the Globalstar LEO communications network, http://www.globalstar.com. The GSP-1620 is configured to a computer systems RS-232 port as a Standard 33.6 data modem. Communications between the flight computer and GSP-1620 are at 38.8 baud. A unique number, #777, is dialed from the modem, and when connected allows direct access to the Internet. Once a connection is established, full duplex operation at 8Kbit is possible between the user, in this case the Maxus rocket, and the Internet.

The purpose of the GSP-1620 packet modem in the Flight Modem is to transmit user data, GPS in this case, from the flight computer to a ground computer connected to the Internet during flight. Globalstar Internet access is currently available in North America only, which created a problem due to the SSC Maxus Test sounding rocket flight occurring in Sweden. The solution to not having Internet access in Northern Europe was to place a Markov test call and record the status of the call while the rocket was in flight. Status data was recorded to the flight computer hard drive during the SSC MAXUS Test flight and analyzed after retrieval of the Flight Modem payload.

3.3 GPS

An ASTECH G12 GPS receiver supplied GPS data for this mission via its RS-422 and was connected to the flight computer RS-422 port. The GPS data format was a set of proprietary data packets containing position, velocity and time solutions as well as data on individual GPS satellites used, Signal to Noise ratios and psuedorange data used for differential solution.

Flight Modem SR SSC Data Flow



Power Breakdown

1. G12 GPS Rcvr…...………2.80W, 12Vdc @ 100mA
2. Flight CPU…………...…12.0W, 12Vdc @ 1A
3. Pre-Amp……………....…0.20W, 12Vdc @ 40mA
4. GSP1620…………...…...5.40W, 12Vdc @ 450mA

TOTAL……….20.4W

0.2W @ 5Vdc & 20.2W @ 12Vdc

4.0 Flight Modem Data

The data recorded by the Flight Computer before, during, and after the SSC Maxus Test rocket space flight required much reformatting and conversion to engineering units before it could be plotted in an easy to understand format. GPS data and GSP-1620 packet data modem status data were recorded to separate files on the Flight Computer disk with no correlation between start and stop times of the files possible. All data, GPS and GSP-1620 packet data modem, were recorded without the aid of a time stamp. GPS data contains time as part of its data format so it can easily be plotted.. The GSP-1620 modem status data did not include time information for this flight. To determine periods of activity between the GSP-1620 packet data modem and Globalstar, Call Activity Records (CPD) and Call Detail Records (CDR) were requested and received from the Finland Globalstar ground station which indicated usage of the GSP-1620 modem for billing purposes. Activity and detail records indicate call start and stop times, latitude and longitude of the call location, satellite used to make the call, and reason for disconnects. CDR data was matched to GSP-1620 status data recorded during the flight. Start times taken from the CDR provided start times and stop times. Time is then incremented by adding the call duration time, which is included in the flight modem status recorded during the flight, to the CDR data start time.

Signal strength information is provided by the GSP-1620 in response to a status command being issued to the modem. The Received Signal Strength Indicator (RSSI) values are 0,1,2,3,4, which correspond to signal above noise minus coding gain. All values are worst case. 4 =- 17, 3 = -19, 2 = -21, 1 = -23, 0 = -25.
Coding gain is equal to 21dB for Walsh plus 5.5dB for convolutional for a total of 26.5dB. Received signal strength for plotting purposes is better explained as signal to noise or Eb/No which is why conversion of RSSI values to EB/No was performed in this case. A better understanding of the RSSI values and a more exact conversion to signal strength should be requested from Globalstar. RSSI value of 2 or more is sufficient to make a connection between the 1620 packet modem and the Globalstar network.

The number of bad frames divided by total frames determines frame error rate. Bad frames and total frames are included in the Markov call status that was stored to disk at a rate of 10 times a minute. Plotted data shows errors rates of approximately 1%, which is normal for the Globalstar system.

The Globalstar system is designed to vary power levels to the minimum necessary to move user data which conserves system power and allows increased bandwidth for additional users. During phone conversations voice data flow is constantly varying. This varying data flow is throttles the links power levels. The 1% error occurs when power is reduced too much resulting in frame errors. A frame error over a voice circuit would be equal to a 20ms dropout, which is not detectable. Frame errors that occur during a data transmission would result in the error data being retransmitted which would be handled by the TCP/IP software. Maybe a clearer statement that the 1% is recovered and does not represent lost data?

4.1 GSP-1620 Packet Modem Data

Flight Modem data recorded to harddisk and recovered with the payload is ASCII text format and includes both Markov and 1620 modem status information. Actual flight modem data:

```
AT$QCSTATUS SERVICE AVAILABLE: YES
SERVICE MODE: GLOBALSTAR
PROVIDER: GNE Sweden
GATEWAY: 20
RSSI: 2
REGISTRATION: YES
ROAMING: YES
CALL STATE: CALLINPROG
CALL TYPE: MARKOV
CALL DURATION: 6
NUMBER: #627568


OK

AT$QCMSTATS MARKOV RATE: VARIABLE FULL
BIT ERRORS: 00000000
BAD FRAMES: 00000001
TOTAL FRAMES: 00000209
EXPECTED/RECEIVED RATE: 0142 0000 0000 0000
                        0000 007B 0000 0000
                        0000 0000 0027 0000
                        0000 0000 0000 0008
GOOD FRAMES: 0000 0000 0000 0000
ERASURES: 0001 0000 0000 0000
```

4.1.1 Description of GSP-1620 Packet Modem Status

AT$QCSTATUS - Command sent to the 1620 modem.
SERVICE AVAILABLE: YES or NO is self-explanatory
PROVIDER: GNE Sweden – Service Provider (GNE Globalstar Northern Europe)
GATEWAY: 20 – The identification of the Ground Station receiving call. 20 is Finland.
RSSI: 2 – Received Signal Strength Indicator. Values are 0,1,2,3,4

Corresponds to signal above noise minus coding gain.

All values are worst case. 4 =- 17, 3 = -19, 2 = -21, 1 = -23, 0 = -25

REGISTRATION: YES or NO – Modem registration in the Globalstar Network
ROAMING: YES or NO – self explanatory

CALL TYPE: MARKOV, LOOPBACK, DATA – Markov is simulated voice. Looback is as stated, loopback to the caller. Data is as stated. Markov data is generated by the 1620 then sent to the ground station that loops the data back to the user.
CALL DURATION: 25 – Duration in seconds of the current call.
NUMBER:- #627568 – Number dialed for the current call. 627568 is a Markov call. 777 is a Data call.

Description of Markov Call Status:

AT$QCMSTATS – Command sent to 1620
MARKOV RATE: VARIABLE FULL – Data rate of Marcov call which varies from 0, 2400, 4800, 9600 Baud
BIT ERRORS: 00000 – Number of bit errors
BAD FRAMES: 00000 – Number of frames with errors
TOTAL FRAMES:00000- Number of total frames passed between Globalstar ground station and modem.
EXPECTED/RECEIVED RATE: Matrix format of expected to received frames for baud rates of 0, 2400,4800, and 9600.
GOOD FRAMES: Total of good frames passed during the call. Currently not working properly.
ERASURES: Frames erased due to errors for baud rates of 0, 2400, 4800, and 9600.

4.1.2 GSP-1620 Packet Modem Markov Call Status

Markov calls are test calls placed between 1620 packet modems and the Globalstar system simulating a voice call. Data is passed between the Globalstar ground station and the 1620 at 0,1/4, ½, and Full rates which correspond to 0, 1200,2400,4800 and 9600 baud. Following is an example of a Markov status response from the 1620 packet modem and a description:

```
AT$QCMSTATS MARKOV RATE: VARIABLE FULL
BIT ERRORS: 00000000
BAD FRAMES: 00000001
TOTAL FRAMES: 0000028F
EXPECTED/RECEIVED RATE: 00FF 0000 0000 0000
                        0000 008F 0000 0000
                        0000 0000 00B2 0000
                        0000 0000 0000 0038
GOOD FRAMES: 0000 0000 0000 0000
ERASURES: 0001 0000 0000 0000
```

Markov status response is in the form of a 4 x 4 matrix, which corresponds to expected to received frames at the 4 rates the system utilizes. Markov tests all rates possible, which are 0, 2400, 4800, and 9600, or 0, 1/4, 1/2 and full. O rate is noted as time when no data is present which during a phone conversation is >50% of the time.

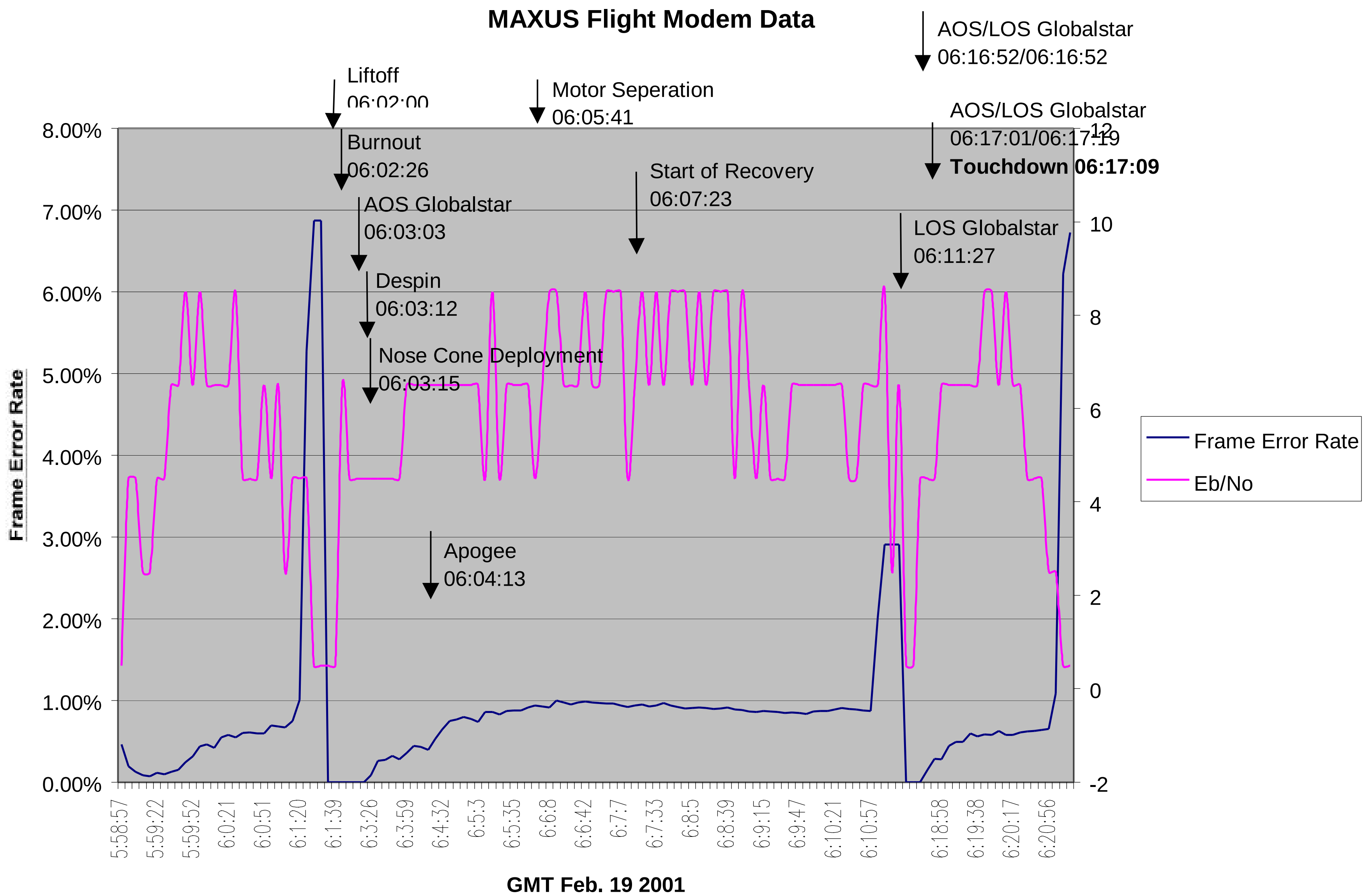
		0	1/4	1/2	Full
EXPECTED/RECEIVED RATE:	0	0A50	0000	0000	0000
	1/4	0004	0637	0001	0000
	1/2	0000	0000	04A9	0000

Full 0000 0000 0000 016B

Erasures are frame errors not processed for a particular rate and should equal the number of bad frames.
ERASURES: 0003 0009 0011 0018
Good Frames is not functioning properly. Good frame counts can be obtained from the matrix.
GOOD FRAMES: 0000 0000 0000 0000
All status values are hex.

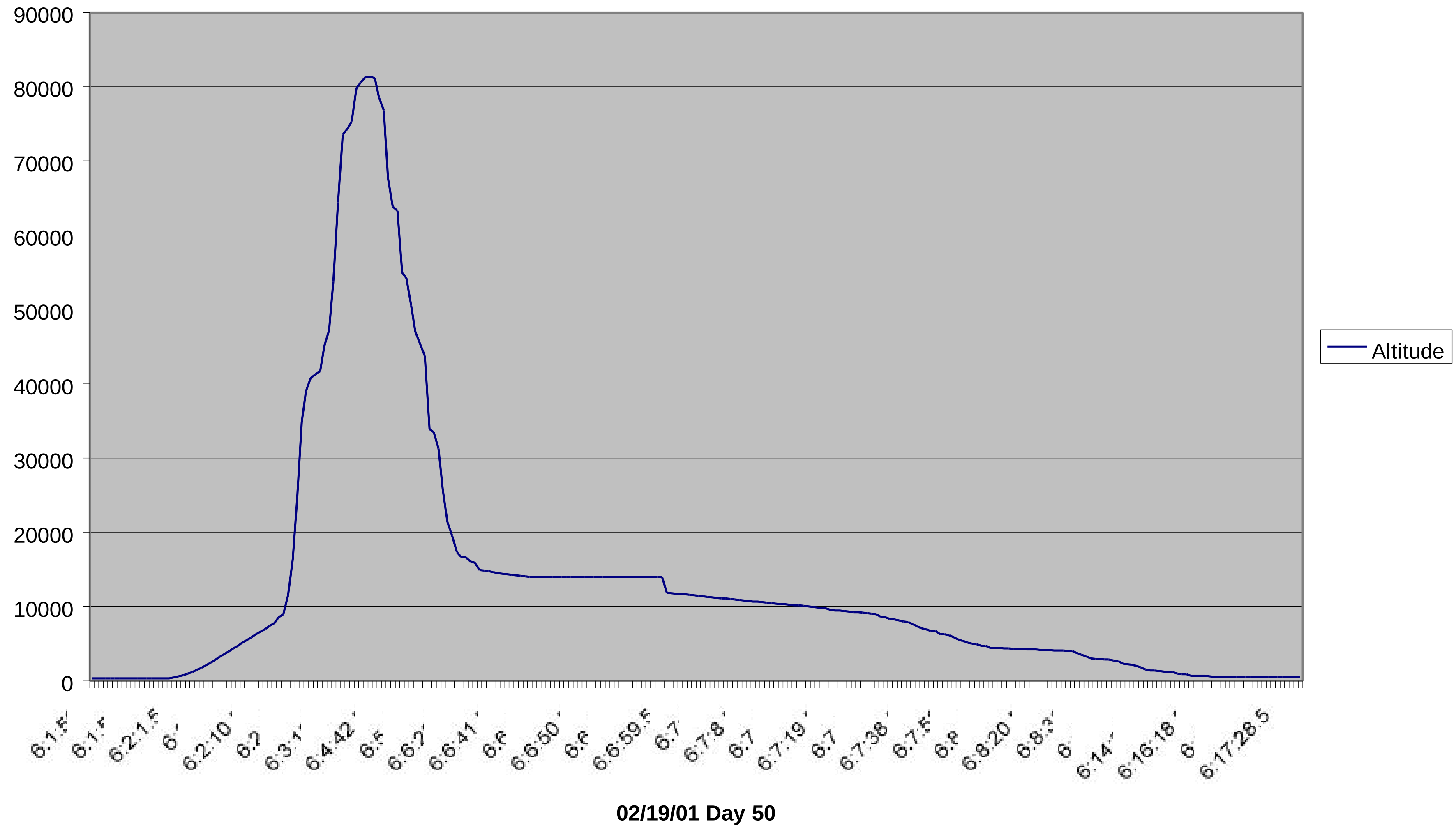
4.2 GPS DATA

GPS data collected by the Flight Modem is unremarkable and matched GPS data present in the conventional payload to ground telemetry data. Other than the Flight Modem recording fewer samples of data during the flight, the recorded data was still of the same quality as seen and recorded on the ground via the telemetry link



MAXUS Flight Modem Data
Liftoff
06:02:00
Motor Seperation
06:05:41
AOS/LOS Globalstar
06:16:52/06:16:52
AOS/LOS Globalstar
06:17:01/06:17:19
Touchdown 06:17:09
Burnout
06:02:26
AOS Globalstar
06:03:03
Despin
06:03:12
Nose Cone Deployment
06:03:15
Start of Recovery
06:07:23
LOS Globalstar
06:11:27
Apogee
06:04:13
Frame Error Rate
8.00%
7.00%
6.00%
5.00%
4.00%
3.00%
2.00%
1.00%
0.00%
12
10
8
6
4
2
0
-2
5:58:57
5:59:22
5:59:52
6:0:21
6:0:51
6:1:20
6:1:39
6:3:26
6:3:59
6:4:32
6:5:3
6:5:35
6:6:8
6:6:42
6:7:7
6:7:33
6:8:5
6:8:39
6:9:15
6:9:47
6:10:21
6:10:57
6:18:58
6:19:38
6:20:17
6:20:56
GMT Feb. 19 2001
Frame Error Rate
Eb/No

MAXUS GPS Data Plot
Captured by Flightmodem



5.0 Data Analysis

5.1 1620 Packet Modem Data

SSC Maxus Test Flight Modem data shows that the GSP-1620 packet data modem successfully called the Globalstar system and maintained the call during most of the flight. Between 06:03:03 and 06:11:27 the GSP-1620 packet data modem was in contact with Globalstar and maintained a 1% error rate that is expected. Variations in signal strength were between RSSI levels of 4 and 3 which is normal for the latitude in which it was operating. It is worth mentioning that connection was maintained during several spacecraft events, which include despin, nosecone deployment, motor separation, and parachute deployment. In addition to the flight aspect, it is worth noting that the system made several connections after the system was on the ground.

During integration of the Flight Modem, it was noted that a constant connection between the GSP-1620 packet data modem and Globalstar was not possible. Connections lasting several minutes were possible and did occur during the SSC Maxus Test flight. The main factor contributing to disconnects was the range between the Flight Modem and Globalstar satellite network. How do we know this?

The Globalstar constellation of satellites is in a 52 degree, 1440 kilometer orbit designed to serve temperate latitudes on earth. Integration and launch of SSC Maxus Test flight occurred at Esrange, Sweden, which is at 67 degree north latitude This added significantly to the range and thus reduced link margin in addition to having lower horizon views. Satellite Tool Kit (STK) was used to determine the orbit of the Globalstar satellites in view during the time of SSC Maxus Test launch from Esrange, Sweden. The following table is a few minutes of STK data that shows Globalstar satellites and their respective azmith, elevation and range from the launch range.

Sat No	Time	Azimuth	Elev	Range km
3	02/19/2001 06:00:00.000	157.072	9.723	3533.15
22	02/19/2001 06:00:00.000	117.831	10.771	3449.03
36	02/19/2001 06:00:00.000	247.275	5.899	3876.95
57	02/19/2001 06:00:00.000	216.277	12.604	3303.13
3	02/19/2001 06:01:00.000	152.798	6.894	3781.57
22	02/19/2001 06:01:00.000	111.203	9.829	3527.51
36	02/19/2001 06:01:00.000	241.197	5.978	3868.7
57	02/19/2001 06:01:00.000	210.91	15.767	3074.3
3	02/19/2001 06:02:00.000	149.137	4.133	4045.51
22	02/19/2001 06:02:00.000	104.98	8.522	3640.11
36	02/19/2001 06:02:00.000	235.147	5.711	3893.2
57	02/19/2001 06:02:00.000	204.506	18.873	2873.01
3	02/19/2001 06:03:00.000	145.98	1.461	4321.44
22	02/19/2001 06:03:00.000	99.239	6.929	3783.5
36	02/19/2001 06:03:00.000	229.234	5.115	3949.7
57	02/19/2001 06:03:00.000	196.925	21.744	2706.07

4	02/19/2001 06:03:27.860	266.791	0	4487.99
3	02/19/2001 06:03:33.740	144.391	0	4480.75
22	02/19/2001 06:04:00.000	94.013	5.13	3953.96
36	02/19/2001 06:04:00.000	223.553	4.22	4036.67
57	02/19/2001 06 :04:00.000	188.134	24.121	2580.65
4	02/19/2001 06:04:27.000	263.838	2.536	4214.4

Note: Globalstar satellites were renamed due to several being destroyed during launch aboard a Delta rocket.

The CDR will show satellites with the new ID while STK displays the original ID.
Use the following key to match STK to Globalstar CDR IDs.

STK Satellite ID	Globalstar Satellite ID in HEX
57	5
58	7
59	9
60	A
61	B
62	C
63	D
64	10

The following is a list of events that occurred before during and after the Maxus flight February 19, 2001:

05:58:57 – Flight Modem places a Markov call to Global star and begins recording Markov status.
06:01:41 – Flight Modem is disconnected from Globalstar for unknown reason.
06:02:00 – Liftoff of Maxus
06:02:26 – Improved Orion motor burn out.
06:03:04 – Flight Modem places a Markov call to Global star and begins recording Markov status.
06:03:12 – Start of Despin Sequence
06:03:15 – Nose Cone Deployment
06:05:41 – Motor Separation
06:07:23 – Start of Recovery Sequence, Parachute Deployment
06:11:27 – Flight Modem is disconnected from Globalstar for unknown reason.
06:16:52 – Flight Modem connects then quickly disconnects from Globalstar
06:17:01 – Flight Modem places a Markov call to Globalstar
06:17:09 – Touchdown of Maxus payload
06:17:19 - Flight Modem is disconnected from Globalstar for unknown reason.
06:18:26 - Flight Modem places a Markov call to Global star and begins recording Markov status.
06:21:24 - Flight Modem is disconnected from Globalstar for unknown reason.

6.0 Conclusion

The data obtained from the first Flight Modem test has proven the concept of using a commercial satellite communications network to relay data from a spacecraft to the ground. However, this flight did not send telemetry data from a spacecraft to the ground due to the absence of a data enabled gateway in Northern Europe. It did prove that if one were available, the results would have been positive.(Someone might reasonably quibble with this statement..) The Flight Modem system demonstrated its ability to control communications between the spacecraft and Globalstar network over which telemetry data at rates to 8Kbit could easily be moved. The Flight Modem archived GPS data during the flight which could have been routed to the GSP-1620 packet data modem for transfer to the ground. It should be noted that with a data enabled gateway, full duplex communications is possible between the spacecraft and the ground.